3

Greenhouse Gas Inventory

An emissions inventory that identifies and quantifies a country's primary anthropogenic[1] sources and sinks of greenhouse gases (GHGs) is essential for addressing climate change. This inventory adheres to both (1) a comprehensive and detailed set of methodologies for estimating sources and sinks of anthropogenic GHGs, and (2) a common and consistent mechanism that enables Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to compare the relative contributions of different emission sources and GHGs to climate change.

By ratifying the Convention, Parties "shall develop, periodically update, publish and make available … national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies…."[2] The United States views the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2011* (1990–2011 Inventory) as an opportunity to fulfill these commitments (U.S. EPA/OAP 2013).

This chapter summarizes the latest information on U.S. anthropogenic GHG emission trends from 1990 through 2011. To ensure that the U.S. emissions inventory is comparable with those of other UNFCCC Parties, the estimates presented here were calculated using methodologies consistent with those recommended in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/OECD/IEA 1997), the Intergovernmental Panel on Climate Change (IPCC) *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000), and the IPCC *Good Practice Guidance for Land Use, Land-Use Change, and Forestry* (IPCC 2003). Additionally, the U.S. emissions inventory has continued to incorporate new methodologies and data from the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2006). The structure of the 1990–2011 Inventory is consistent with the UNFCCC guidelines for inventory reporting (UNFCCC 2006). For most source categories, the IPCC methodologies were expanded, resulting in a more comprehensive and detailed estimate of emissions (Box 3-1). Consistent with the 1990–2011 Inventory, emissions in this chapter are presented in teragrams[3] of carbon dioxide equivalents (Tg CO_2e).[4]

BACKGROUND INFORMATION

GHGs trap heat and make the planet warmer. The most important GHGs directly emitted as a result of human activities include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and several other fluorine-containing halogenated substances. Although the direct GHGs CO_2, CH_4, and N_2O occur naturally in the atmosphere, human activities have changed their atmospheric concentrations. From the pre-industrial era (i.e., ending about 1750) to 2010, concentrations of CO_2, CH_4, and N_2O have increased globally by 39, 158, and 18 percent, respectively (IPCC 2007 and NOAA/ESRL 2009). The 1990–2011 Inventory estimates the total national GHG emissions and removals associated with human activities across the United States.

[1] The term "anthropogenic," in this context, refers to GHG emissions and removals that are a direct result of human activities or are the result of natural processes that have been affected by human activities (IPCC/UNEP/OECD/IEA 1997).

[2] Article 4(1)(a) of the UNFCCC (also identified in Article 12). Subsequent decisions by the Conference of the Parties elaborated the role of Annex I Parties in preparing national inventories. *See* http://unfccc.int.

[3] One teragram is equal to 1,012 grams or one million metric tons.

[4] Further information is provided in this chapter's Box 3-2: Global Warming Potentials.

Box 3-1 **Recalculations of Inventory Estimates**

Each year, emission and sink estimates are recalculated and revised for all years in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, as attempts are made to improve both the analyses themselves, through the use of better methods or data, and the overall usefulness of the report. In this effort, the United States follows the 2006 IPCC guidelines (IPCC 2006), which state, "Both methodological changes and refinements over time are an essential part of improving inventory quality. It is good practice to change or refine methods "when: available data have changed; the previously used method is not consistent with the IPCC guidelines for that category; a category has become key; the previously used method is insufficient to reflect mitigation activities in a transparent manner; the capacity for inventory preparation has increased; new inventory methods become available; and for correction of errors." In general, recalculations are made to the U.S. GHG emission estimates either to incorporate new methodologies or, most commonly, to update recent historical data.

In each inventory report, the results of all methodology changes and historical data updates are presented in the "Recalculations and Improvements" chapter. If applicable, detailed descriptions of each recalculation are contained within each emission source's description in the report. In general, when methodological changes have been implemented, the entire time series has been recalculated to reflect the change, per the 2006 IPCC guidelines (IPCC 2006). In the case of the most recent inventory report, the time series is 1990 through 2011. Changes in historical data are generally the result of changes in statistical data supplied by other agencies. References for the data are provided for additional information.

More information on the most recent changes is provided in the "Recalculations and Improvements" chapter of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2011* (U.S. EPA/OAP 2013), and previous inventory reports can further describe the changes in calculation methods and data since the *U.S. Climate Action Report 2010* (U.S. DOS 2010).

RECENT TRENDS IN U.S. GREENHOUSE GAS EMISSIONS AND SINKS

In 2011, total U.S. GHG emissions were 6,702.3 Tg CO_2e. Total U.S. emissions have increased by 8.4 percent from 1990 to 2011. Emissions decreased from 2010 to 2011 by 1.6 percent (108.0 Tg CO_2e), due to a decrease in the carbon intensity of fuels consumed to generate electricity resulting from lower coal consumption, higher natural gas consumption, and significantly higher use of hydropower. Additionally, relatively mild winter conditions, especially in the South Atlantic region of the United States where electricity is an important heating fuel, resulted in an overall decrease in electricity demand in most sectors. Since 1990, U.S. emissions have increased at an average annual rate of 0.4 percent.

Figures 3-1 through 3-3 illustrate the overall trends in total U.S. GHG emissions by gas, annual changes, and absolute change since 1990. Table 3-1 provides a detailed summary of U.S. GHG emissions and sinks for 1990 through 2011. These data and trends are further detailed in the 1990–2011 Inventory. In 2011, total net U.S. GHG emissions (i.e., including net sequestration from land use, land-use change, and forestry [LULUCF] activities) were 5,797.3 Tg CO_2e. This represents a 6.5 percent reduction below 2005 levels.

Figure 3-4 illustrates the relative contribution of the direct GHGs to total U.S. emissions in 2011. The primary GHG emitted by human activities in the United States was CO_2, representing approximately 83.7 percent of total GHG emissions. The largest source of CO_2, and of overall GHG emissions, was fossil fuel combustion. CH_4 emissions, which have decreased by 8.2 percent since 1990, resulted primarily from natural gas systems, enteric fermentation associated with domestic livestock, and decomposition of wastes in landfills. Agricultural soil management, mobile source fuel combustion, and stationary source fuel combustion were the major sources of N_2O emissions. Emissions from substitutes for ozone-depleting substances and emissions of hydrofluorocarbon (HFC)-23 (fluoroform) during the production of hydrochlorofluorocarbon (HCFC)-22 were the primary contributors to aggregate HFC emissions. Perfluorocarbon (PFC) emissions resulted from semiconductor manufacturing and as a by-product of primary aluminum production, while electrical transmission and distribution systems accounted for most sulfur hexafluoride (SF_6) emissions.

Overall, from 1990 to 2011, total emissions of CO_2 increased by 504.0 Tg CO_2e (9.9 percent), while total emissions of CH_4 decreased by 52.7 Tg CO_2e (8.2 percent), and N_2O increased by 12.6 Tg CO_2e (3.6 percent). During the same period, aggregate weighted emissions of HFCs,

Figure 3-1 **U.S. Greenhouse Gas Emissions by Gas**

Between 2007 (2010 CAR data) and 2011, U.S. emissions from all GHGs declined by a total of 561 Tg CO_2e, or 7.2 percent. Total U.S. emissions increased by 8.4 percent from 1990 to 2011.

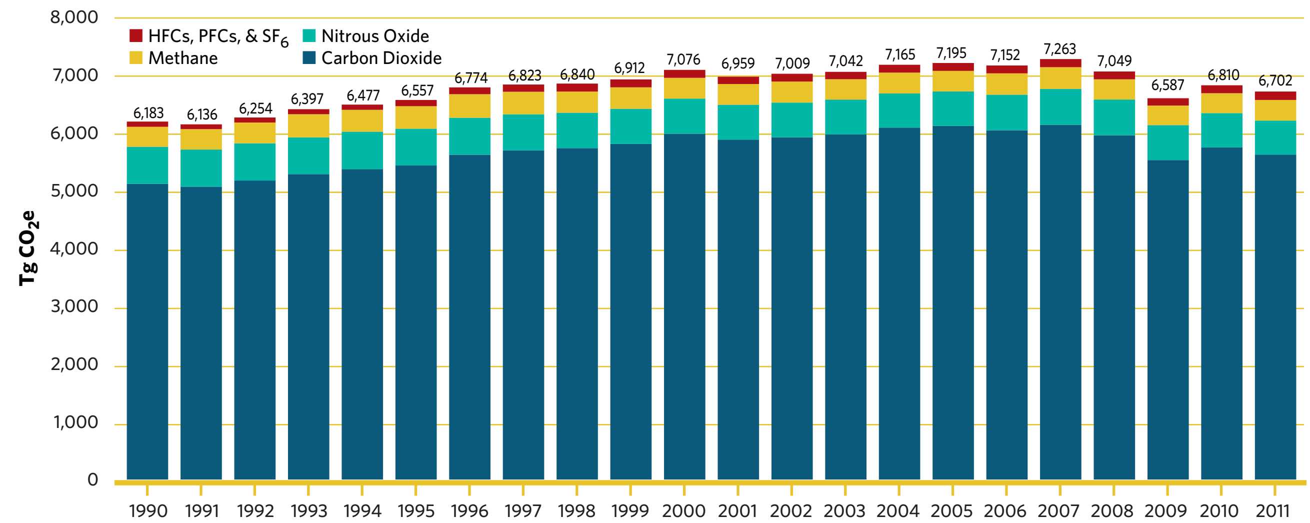


Figure 3-2 **Annual Percentage Change in U.S. Greenhouse Gas Emissions**

Between 2008 and 2011, U.S. GHG emissions fell by 4.9 percent. The average annual rate of increase from 1991 through 2011 was 0.4 percent.

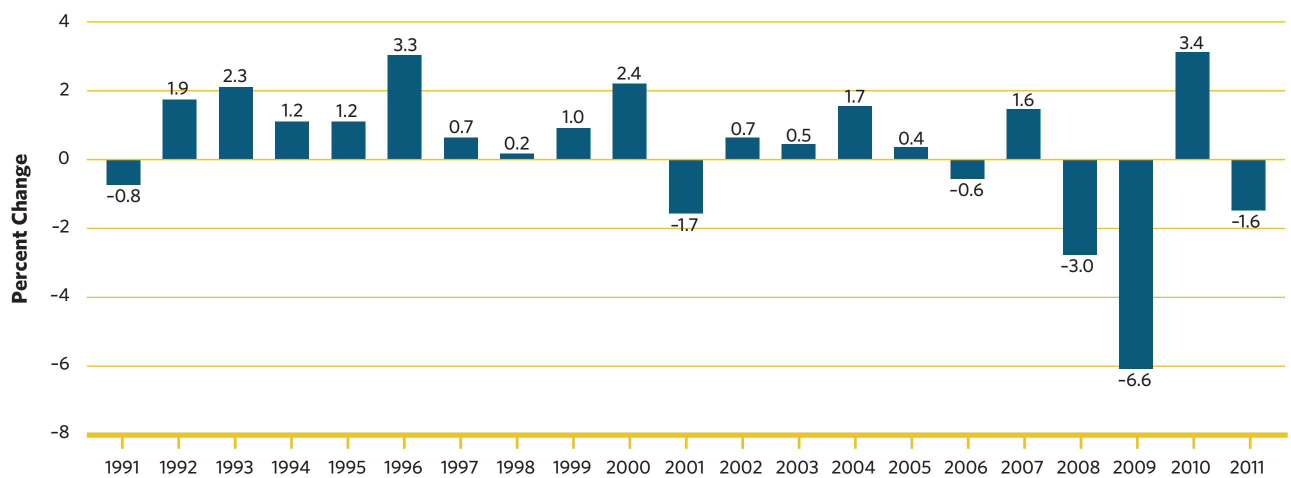


Figure 3-3 **Cumulative Change in Annual U.S. Greenhouse Gas Emissions Relative to 1991**

From 1991 through 2011, total U.S. GHG emissions rose by 159 Tg CO_2e, an increase of 9.2 percent. Between 2007 (2010 CAR data) and 2011, U.S. GHG emissions declined by 561 Tg CO_2e, or 7.7 percent.

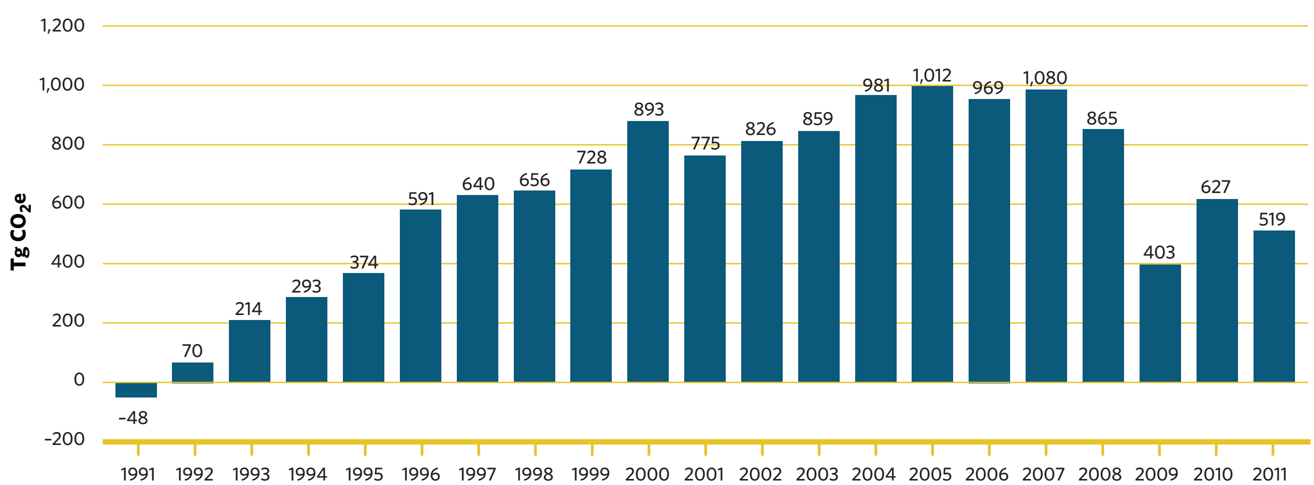


Table 3-1 **Recent Trends in U.S. Greenhouse Gas Emissions and Sinks** (Tg CO_2e)

In 2011, total U.S. GHG emissions were 6,702.3 Tg CO_2e, representing a 8.4 percent increase since 1990, and a 7.7 percent decrease since 2007 (2010 CAR data).

Gas/Source	1990	2005	2007	2008	2009	2010	2011
Carbon Dioxide (CO_2)	**5,108.8**	**6,109.3**	**6,128.6**	**5,944.8**	**5,517.9**	**5,736.4**	**5,612.9**
Fossil Fuel Combustion	4,748.5	5,748.7	5,767.7	5,590.6	5,222.4	5,408.1	5,277.2
Electricity Generation	1,820.8	2,402.1	2,412.8	2,360.9	2,146.4	2,259.2	2,158.5
Transportation	1,494.0	1,891.7	1,904.7	1,816.0	1,749.2	1,763.9	1,745.0
Industrial	848.6	823.4	844.4	802.0	722.6	780.2	773.2
Residential	338.3	357.9	341.6	347.0	337.0	334.6	328.8
Commercial	219.0	223.5	218.9	223.8	223.4	221.8	222.1
U.S. Territories	27.9	50.0	45.2	41.0	43.8	49.6	49.7
Non-Energy Use of Fuels	117.4	142.7	134.9	139.5	124.0	132.8	130.6
Iron & Steel and Metallurgical Coke Production	99.8	66.7	71.3	66.8	43.0	55.7	64.3
Natural Gas Systems	37.7	29.9	30.9	32.6	32.2	32.3	32.3
Cement Production	33.3	45.2	44.5	40.5	29.0	30.9	31.6
Lime Production	11.5	14.3	14.6	14.3	11.2	13.1	13.8
Incineration of Waste	8.0	12.5	12.7	11.9	11.7	12.0	12.0
Other Process Uses of Carbonates	4.9	6.3	7.4	5.9	7.6	9.6	9.2
Ammonia Production	13.0	9.2	9.1	7.9	7.9	8.7	8.8
Cropland Remaining Cropland	7.1	7.9	8.2	8.6	7.2	8.4	8.1
Urea Consumption for Nonagricultural Purposes	3.8	3.7	4.9	4.1	3.4	4.4	4.3
Petrochemical Production	3.4	4.3	4.1	3.6	2.8	3.5	3.5
Aluminum Production	6.8	4.1	4.3	4.5	3.0	2.7	3.3
Soda Ash Production and Consumption	2.8	3.0	2.9	3.0	2.6	2.7	2.7
Titanium Dioxide Production	1.2	1.8	1.9	1.8	1.6	1.8	1.9
Carbon Dioxide Consumption	1.4	1.3	1.9	1.8	1.8	2.2	1.8
Ferroalloy Production	2.2	1.4	1.6	1.6	1.5	1.7	1.7
Glass Production	1.5	1.9	1.5	1.5	1.0	1.5	1.3
Zinc Production	0.6	1.0	1.0	1.2	0.9	1.2	1.3
Phosphoric Acid Production	1.5	1.3	1.2	1.2	1.0	1.1	1.2
Wetlands Remaining Wetlands	1.0	1.1	1.0	1.0	1.1	1.0	0.9
Lead Production	0.5	0.6	0.6	0.5	0.5	0.5	0.5
Petroleum Systems	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.1	0.2	0.2
Land Use, Land-Use Change, and Forestry (Sink)[a]	*(794.5)*	*(997.8)*	*(929.2)*	*(902.6)*	*(882.6)*	*(888.8)*	*(905.0)*
Wood Biomass and Ethanol Consumption[b]	*218.6*	*228.7*	*238.3*	*251.7*	*245.1*	*264.5*	*264.5*
International Bunker Fuels[c]	*103.5*	*113.1*	*115.3*	*114.3*	*106.4*	*117.0*	*111.3*

Table 3-1 (Continued) **Recent Trends in U.S. Greenhouse Gas Emissions and Sinks** (Tg CO_2e)

Gas/Source	1990	2005	2007	2008	2009	2010	2011
Methane (CH_4)	**639.9**	**593.6**	**618.6**	**618.8**	**603.8**	**592.7**	**587.2**
Natural Gas Systems	161.2	159.0	168.4	163.4	150.7	143.6	144.7
Enteric Fermentation	132.7	137.0	141.8	141.4	140.6	139.3	137.4
Landfills	147.8	112.5	111.6	113.6	113.3	106.8	103.0
Coal Mining	84.1	56.9	57.9	67.1	70.3	72.4	63.2
Manure Management	31.5	47.6	52.4	51.5	50.5	51.8	52.0
Petroleum Systems	35.2	29.2	29.8	30.0	30.5	30.8	31.5
Wastewater Treatment	15.9	16.5	16.6	16.6	16.5	16.4	16.2
Forestland Remaining Forestland	2.5	8.0	14.4	8.7	5.7	4.7	14.2
Rice Cultivation	7.1	6.8	6.2	7.2	7.3	8.6	6.6
Stationary Combustion	7.5	6.6	6.4	6.6	6.3	6.3	6.3
Abandoned Underground Coal Mines	6.0	5.5	5.3	5.3	5.1	5.0	4.8
Petrochemical Production	2.3	3.1	3.3	2.9	2.9	3.1	3.1
Mobile Combustion	4.6	2.4	2.1	1.9	1.8	1.8	1.7
Composting	0.3	1.6	1.7	1.7	1.6	1.5	1.5
Iron & Steel and Metallurgical Coke Production	1.0	0.7	0.7	0.6	0.4	0.5	0.6
Field Burning of Agricultural Residues	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Ferroalloy Production	+	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[c]	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
Nitrous Oxide (N_2O)	**344.3**	**356.1**	**376.1**	**349.7**	**338.7**	**343.9**	**356.9**
Agricultural Soil Management	227.9	237.5	252.3	245.4	242.8	244.5	247.2
Stationary Combustion	12.3	20.6	21.2	21.1	20.7	22.6	22.0
Mobile Combustion	44.0	36.9	29.0	25.5	22.7	20.7	18.5
Manure Management	14.4	17.1	18.0	17.8	17.7	17.8	18.0
Nitric Acid Production	18.2	16.9	19.7	16.9	14.0	16.8	15.5
Forestland Remaining Forestland	2.1	6.9	12.1	7.4	5.0	4.2	11.9
Adipic Acid Production	15.8	7.4	10.7	2.6	2.8	4.4	10.6
Wastewater Treatment	3.5	4.7	4.8	4.9	5.0	5.1	5.2
N_2O from Product Uses	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Composting	0.4	1.7	1.8	1.9	1.8	1.7	1.7
Settlements Remaining Settlements	1.0	1.5	1.6	1.5	1.4	1.5	1.5
Incineration of Waste	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Field Burning of Agricultural Residues	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wetlands Remaining Wetlands	+	+	+	+	+	+	+
International Bunker Fuels[c]	*0.9*	*1.0*	*1.0*	*1.0*	*0.9*	*1.0*	*1.0*

Table 3-1 (Continued) **Recent Trends in U.S. Greenhouse Gas Emissions and Sinks** (Tg CO_2e)

Gas/Source	1990	2005	2007	2008	2009	2010	2011
Hydrofluorocarbons (HFCs)	**36.9**	**115.0**	**120.0**	**117.5**	**112.0**	**121.3**	**129.0**
Substitution of Ozone-Depleting Substances[d]	0.3	99.0	102.7	103.6	106.3	114.6	121.7
HCFC-22 Production	36.4	15.8	17.0	13.6	5.4	6.4	6.9
Semiconductor Manufacture	0.2	0.2	0.3	0.3	0.2	0.4	0.3
Perfluorocarbons (PFCs)	**20.6**	**6.2**	**7.7**	**6.6**	**4.4**	**5.9**	**7.0**
Semiconductor Manufacture	2.2	3.2	3.8	3.9	2.9	4.4	4.1
Aluminum Production	18.4	3.0	3.8	2.7	1.6	1.6	2.9
Sulfur Hexafluoride (SF_6)	**32.6**	**15.0**	**12.3**	**11.4**	**9.8**	**10.1**	**9.4**
Electrical Transmission and Distribution	26.7	11.1	8.8	8.6	8.1	7.8	7.0
Magnesium Production and Processing	5.4	2.9	2.6	1.9	1.1	1.3	1.4
Semiconductor Manufacture	0.5	1.0	0.8	0.9	0.7	1.0	0.9
Total	**6,183.3**	**7,195.3**	**7,263.2**	**7,048.8**	**6,586.6**	**6,810.3**	**6,702.3**
Net Emissions (Sources and Sinks)	**5,388.7**	**6,197.4**	**6,334.0**	**6,146.2**	**5,704.0**	**5,921.5**	**5,797.3**

+ Does not exceed 0.05 Tg CO_2e.

[a] Parentheses indicate negative values or sequestration. The net CO_2 flux total includes both emissions and sequestration, and constitutes a net sink in the United States. Sinks are only included in net emissions totals.

[b] Emissions from Wood Biomass and Ethanol Consumption are not included specifically in summing energy sector totals. Net carbon fluxes from changes in biogenic carbon reservoirs are accounted for in the estimates for Land Use, Land-Use Change, and Forestry.

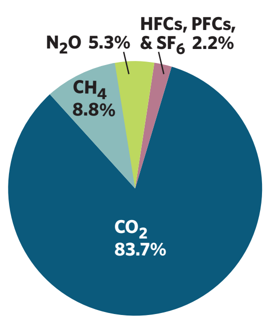
[c] Emissions from International Bunker Fuels are not included in totals.

[d] Small amounts of PFC emissions also result from this source.

Note: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Figure 3-4 **2011 Greenhouse Gas Emissions by Gas**

The primary GHG emitted by human activities in the United States was CO_2, representing approximately 83.7 percent of total GHG emissions.



Note: Percentages Based on Tg CO_2e.

Source: U.S. EPA/OAP 2013.

PFCs, and SF_6 rose by 55.1 Tg CO_2e (61.1 percent). From 1990 to 2011, HFCs increased by 92.0 Tg CO_2e (249.3 percent), PFCs decreased by 13.6 Tg CO_2e (66.1 percent), and SF_6 decreased by 23.3 Tg CO_2e (71.3 percent).

Despite being emitted in smaller quantities relative to the other principal GHGs, emissions of HFCs, PFCs, and SF_6 are significant because many of these gases have extremely high global warming potentials and, in the cases of PFCs and SF_6, long atmospheric lifetimes (Box 3-2). Conversely, U.S. GHG emissions were partly offset by carbon sequestration in forests, trees in urban areas, agricultural soils, and landfilled yard trimmings and food scraps, which, in aggregate, offset 13.5 percent of total emissions in 2011. The following sections describe each gas's contribution to total U.S. GHG emissions in more detail.

Carbon Dioxide Emissions

The global carbon cycle is made up of large carbon flows and reservoirs. Since the Industrial Revolution (i.e., about 1750), global atmospheric concentrations of CO_2 have risen by about 39 percent (IPCC 2007 and NOAA/ESLR 2009), principally due to the combustion of fossil fuels. Within the United States, fossil fuel combustion accounted for 94.0 percent of CO_2 emissions in 2011. Globally, approximately 31,780 Tg of CO_2 were added to the atmosphere through the combustion of fossil fuels in 2010, of which the United States accounted for about 18 percent.[5] Changes in land use and forestry practices can also increase emissions of CO_2 (e.g., through conversion of forestland to agricultural or urban use) or can result in CO_2 removals (or sinks, e.g., through net additions to forest biomass). In addition to fossil fuel combustion, several other sources emit significant quantities of CO_2. These sources include non-energy use of fuels, iron and steel production, and cement production (Figure 3-5).

As the largest source of U.S. GHG emissions, CO_2 from fossil fuel combustion has accounted for approximately 78 percent of GWP-weighted emissions since 1990, and was approximately 79

[5] Global CO_2 emissions from fossil fuel combustion were taken from the U.S. Department of Energy, Energy Information Administration, International Energy Statistics 2010. *See* http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm.

Box 3-2 **Global Warming Potentials**

Gases in the atmosphere can contribute to the greenhouse effect both directly and indirectly. Direct effects occur when the gas itself absorbs radiation. Indirect radiative forcing occurs when chemical transformations of the substance produce other GHGs, when a gas influences the atmospheric lifetimes of other gases, and/or when a gas affects atmospheric processes that alter Earth's radiative balance (e.g., affect cloud formation or albedo).[6] The IPCC developed the global warming potential (GWP) concept to compare the ability of each GHG to trap heat in the atmosphere relative to another gas.

The GWP of a GHG is defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kilogram (kg) of a trace substance relative to that of 1 kg of a reference gas (IPCC 2001). Direct radiative effects occur when the gas itself is a GHG. The reference gas used is CO_2; therefore, GWP-weighted emissions are measured in teragrams of carbon dioxide equivalents ($TgCO_2e$).[7] All gases in this chapter are presented in units of Tg CO_2e.

The UNFCCC reporting guidelines for national inventories were most recently updated in 2006 (IPCC 2006), but continue to require the use of GWPs from the IPCC Second Assessment Report (SAR) (IPCC 1996). This requirement ensures that current estimates of aggregate GHG emissions for 1990 to 2011 are consistent with estimates developed prior to the publication of the IPCC Third Assessment Report (IPCC 2001) and the IPCC Fourth Assessment Report (IPCC 2007). Therefore, to comply with international reporting standards under the UNFCCC, the United States reports its official emission estimates using the SAR GWP values listed in Table 3-2.

GWPs are not provided for carbon monoxide (CO), oxides of nitrogen (NO_x), nonmethane volatile organic compounds (NMVOCs), sulfur dioxide (SO_2), black carbon, and aerosols because there is no agreed-upon method to estimate the contribution of gases that are short-lived in the atmosphere, are spatially variable, or have only indirect effects on radiative forcing (IPCC 1996).

Figure 3-5 **2011 U.S. Sources of CO_2 Emissions** (Tg CO_2e)

In 2011, CO_2 accounted for 83.7 percent of U.S. GHG emissions, with fossil fuel combustion accounting for 94.0 percent of CO_2 emissions.

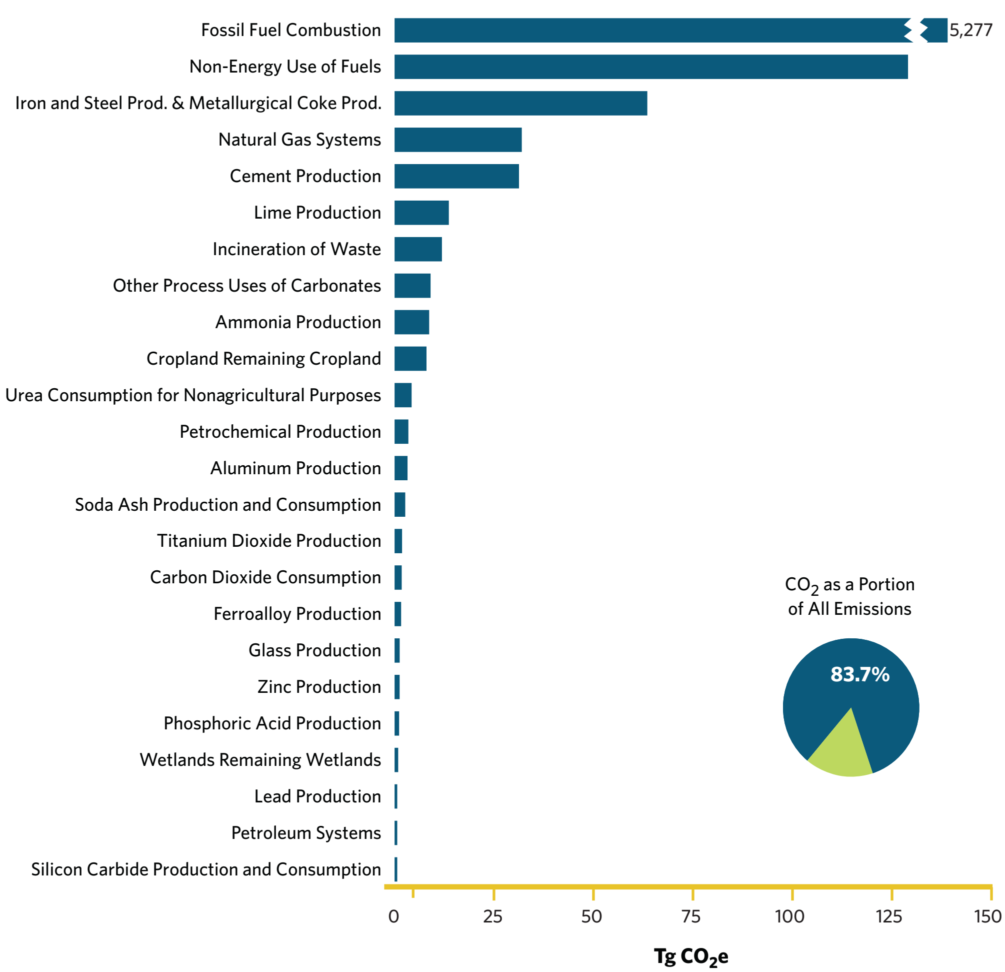


Table 3-2 **Global Warming Potentials Used in This Report** (100-Year Time Horizon)

Gas	GWP
CO_2	1
CH_4*	21
N_2O	310
HFC-23	11,700
HFC-32	650
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-4310mee	1,300
CF_4	6,500
C_2F_6	9,200
C_4F_{10}	7,000
C_6F_{14}	7,400
SF_6	23,900

Source: IPCC 1996.

* The CH_4 GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone andstratos-pheric water vapor. The indirect effect due to the production of CO_2 is not included.

Note: GWP = global warming potential; CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; HFC = hydrofluorocarbon; CF_4 = tetrafluoromethane; C_2F_6 = hexafluoroethane; C_4F_{10} = perfluorobutane; C_6F_{14} = perfluorohexane or tetradecafluorohexane; SF_6 = sulfur hexafluoride.

[6] Albedo is a measure of Earth's reflectivity, and is defined as the fraction of the total solar radiation incident on a body that is reflected by it.

[7] Carbon comprises 12/44ths of carbon dioxide by weight.

percent of total GWP-weighted emissions in 2011. Emissions of CO_2 from fossil fuel combustion increased at an average annual rate of 0.5 percent from 1990 to 2011. The fundamental factors influencing this trend include (1) a generally growing domestic economy over the last 22 years, and (2) an overall growth in emissions from electricity generation and transportation activities. Between 1990 and 2011, CO_2 emissions from fossil fuel combustion increased from 4,748.5 Tg CO_2e to 5,277.2 Tg CO_2e—an 11.1 percent total increase over the 22-year period. From 2010 to 2011, these emissions decreased by 130.9 Tg CO_2e (2.4 percent).

Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends. Changes in CO_2 emissions from fossil fuel combustion are influenced by many long-term and short-term factors, including population and economic growth, energy price fluctuations, technological changes, and seasonal temperatures. In the short term, the overall consumption of fossil fuels in the United States fluctuates primarily in response to changes in general economic conditions, energy prices, weather, and the availability of nonfossil alternatives.

For example, a year with increased consumption of goods and services, low fuel prices, severe summer and winter weather conditions, nuclear plant closures, and lower precipitation feeding hydroelectric dams would likely have proportionally greater fossil fuel consumption than a year with poor economic performance, high fuel prices, mild temperatures, and increased output from nuclear and hydroelectric plants. In the long term, energy consumption patterns respond to changes that affect the scale of consumption (e.g., population, number of cars, and size of houses); the efficiency with which energy is used in equipment (e.g., cars, power plants, steel mills, and light bulbs); and behavioral choices (e.g., walking, bicycling, or telecommuting to work instead of driving).

The five major fuel-consuming sectors contributing to CO_2 emissions from fossil fuel combustion are electricity generation, transportation, industrial, residential, and commercial. The electricity generation sector produces CO_2 emissions as it consumes fossil fuel to provide electricity to one of the other four "end-use" sectors. For the discussion that follows, electricity generation emissions have been distributed to each end-use sector on the basis of each sector's share of aggregate electricity consumption. This method of distributing emissions assumes that each end-use sector consumes electricity that is generated from the national average mix of fuels according to their carbon intensity. Emissions from electricity generation are also addressed separately after the end-use sectors have been discussed.

Note that emissions from U.S. territories are calculated separately due to a lack of specific consumption data for the individual end-use sectors. Figures 3-6 and 3-7 and Table 3-3 summarize CO_2 emissions from fossil fuel combustion by end-use sector.

Figure 3-6 **2011 U.S. CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type**

In 2011, U.S. transportation sector emissions were primarily from petroleum consumption, while electricity generation emissions were primarily from coal consumption.

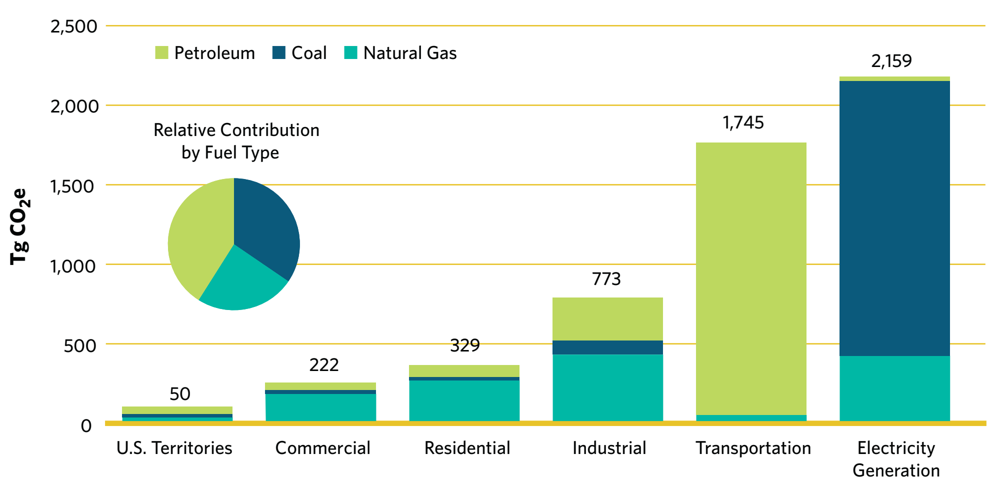


Figure 3-7 **2011 U.S. End-Use Sector Emissions of CO_2, CH_4, and N_2O from Fossil Fuel Combustion**

In 2011, direct fossil fuel combustion accounted for the vast majority of fossil fuel-related CO_2 emissions from the transportation sector (mostly petroleum combustion). Electricity consumption indirectly accounted for most of the fossil fuel-related CO_2 emissions from the commercial, residential, and industrial sectors (mostly coal combustion).

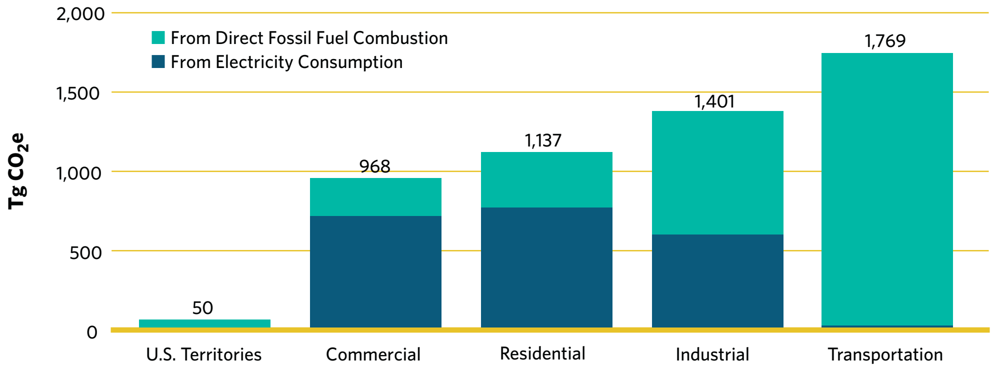


Table 3-3 **CO_2 Emissions from Fossil Fuel Combustion by Fuel-Consuming End-Use Sector** (Tg CO_2e)

The figures below reflect the distribution of electricity generation emissions to each of the four end-use sectors on the basis of each sector's share of aggregate electricity consumption. Between 2007 (2010 CAR data) and 2011, CO_2 emissions decreased by 490.5 Tg CO_2e, or 8.4 percent.

End-Use Sector	1990	2005	2007	2008	2009	2010	2011
Transportation	**1,497.0**	**1,896.5**	**1,909.7**	**1,820.7**	**1,753.7**	**1,768.4**	**1,749.3**
Combustion	1,494.0	1,891.7	1,904.7	1,816.0	1,749.2	1,763.9	1,745.0
Electricity	3.0	4.7	5.1	4.7	4.5	4.5	4.3
Industrial	**1,535.3**	**1,560.4**	**1,559.9**	**1,499.3**	**1,324.6**	**1,421.3**	**1,392.1**
Combustion	848.6	823.4	844.4	802.0	722.6	780.2	773.2
Electricity	686.7	737.0	715.4	697.3	602.0	641.1	618.9
Residential	**931.4**	**1,214.7**	**1,205.2**	**1,189.9**	**1,123.5**	**1,175.0**	**1,125.6**
Combustion	338.3	357.9	341.6	347.0	337.0	334.6	328.8
Electricity	593.0	856.7	863.5	842.9	786.5	840.4	796.9
Commercial	**757.0**	**1,027.2**	**1,047.7**	**1,039.8**	**976.8**	**993.9**	**960.5**
Combustion	219.0	223.5	218.9	223.8	223.4	220.6	222.1
Electricity	538.0	803.7	828.8	816.0	753.5	773.3	738.4
U.S. Territories[a]	**27.9**	**50.0**	**45.2**	**41.0**	**43.8**	**49.6**	**49.7**
Total	**4,748.5**	**5,748.7**	**5,767.7**	**5,590.6**	**5,222.4**	**5,408.1**	**5,277.2**
Electricity Generation	**1,820.8**	**2,402.1**	**2,412.8**	**2,360.9**	**2,146.4**	**2,259.2**	**2,158.5**

[a] Fuel consumption by U.S. territories (i.e., American Samoa, Guam, Puerto Rico, U.S. Virgin Islands, Wake Island, and other U.S. Pacific Islands) is included.

Note: Totals may not sum due to independent rounding.

Transportation End-Use Sector

Transportation activities (excluding international bunker fuels) accounted for 33 percent of CO_2 emissions from fossil fuel combustion in 2011.[8] Virtually all of the energy consumed in this end-use sector came from petroleum products. Nearly 65 percent of the emissions resulted from gasoline consumption for personal vehicle use. The remaining emissions came from other transportation activities, including the combustion of diesel fuel in heavy-duty vehicles and jet fuel in aircraft. From 1990 to 2011, transportation emissions rose by 17 percent, principally because of increased demand for travel and the stagnation of fuel efficiency across the U.S. vehicle fleet.

[8] If emissions from international bunker fuels are included, the transportation end-use sector accounted for 34.5 percent of U.S. emissions from fossil fuel combustion in 2011.

The number of vehicle miles traveled by light-duty motor vehicles (passenger cars and light-duty trucks) increased by 34 percent from 1990 to 2011, as a result of a confluence of factors, including population growth, economic growth, urban sprawl, and low fuel prices over much of this period. However, the more recent trend for transportation has shown a general decline in emissions, due to recent slow growth in economic activity, higher fuel prices, and an associated decrease in the demand for passenger transportation. Additionally, light-duty motor vehicles are also becoming more fuel efficient, due to both a shift in consumer demand and federal and state policies.

Industrial End-Use Sector

Industrial CO_2 emissions, resulting both directly from the combustion of fossil fuels and indirectly from the generation of electricity consumed by industry, accounted for 26 percent of CO_2 from fossil fuel combustion in 2011. Approximately 56 percent of these emissions resulted from direct fossil fuel combustion to produce steam and/or heat for industrial processes. The remaining emissions resulted from consuming electricity for motors, electric furnaces, ovens, lighting, and other applications. In contrast to the other end-use sectors, emissions from industry have steadily declined since 1990. This decline is due to structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and efficiency improvements.

Residential and Commercial End-Use Sectors

The residential and commercial end-use sectors accounted for 21 and 18 percent, respectively, of CO_2 emissions from fossil fuel combustion in 2011. Both sectors relied heavily on electricity for meeting energy demands, with 71 and 77 percent, respectively, of their emissions attributable to electricity consumption for lighting, heating, cooling, and operating appliances. The remaining emissions were due to the consumption of natural gas and petroleum for heating and cooking. Emissions from the residential and commercial end-use sectors have increased by 21 percent and 27 percent since 1990, respectively, due to increasing electricity consumption for lighting, heating, air conditioning, and operating appliances.

Electricity Generation

The United States relies on electricity to meet a significant portion of its energy demands. Electricity generators consumed 36 percent of U.S. energy from fossil fuels and emitted 41 percent of the CO_2 from fossil fuel combustion in 2011. The type of fuel combusted by electricity generators has a significant effect on their emissions. For example, some electricity is generated with low-CO_2-emitting energy technologies, particularly nonfossil options, such as nuclear, hydroelectric, or geothermal energy. Electricity generators relied on coal for approximately 42 percent their total energy requirements in 2011, and accounted for 95 percent of all coal consumed for energy in the United States in 2011.

Recently, the carbon intensity of fuels consumed to generate electricity has decreased, due to lower consumption of coal and higher consumption of natural gas and other energy sources. The discovery and exploitation of vast reserves of natural gas in the United States have reduced its domestic price per energy unit and have sparked demand for natural gas as a baseload fuel for electricity generation. Across the time series, changes in electricity demand and the carbon intensity of fuels used for electricity generation have had a significant impact on CO_2 emissions.

Other significant CO_2 trends include:

- CO_2 emissions from non-energy use of fossil fuels increased by 13.1 Tg CO_2e (11.2 percent) from 1990 through 2011. Emissions from non-energy uses of fossil fuels were 130.6 Tg CO_2e in 2011, which constituted 2.3 percent of total national CO_2 emissions, or approximately the same proportion as in 1990.
- CO_2 emissions from iron and steel production and metallurgical coke production increased by 8.5 Tg CO_2e (15.3 percent) from 2010 to 2011, continuing a two-year trend of increasing emissions, primarily due to increased steel production associated with improved economic conditions. Despite this, from 1990 through 2011, emissions declined by 35.5 Tg CO_2e (35.6 percent), as a result of the restructuring of the industry, technological improvements, and increased scrap utilization.

- In 2011, CO_2 emissions from cement production increased by 0.7 Tg CO_2e (2.3 percent) from 2010. After decreasing in 1991 by 2.2 percent from 1990 levels, emissions from cement production grew every year through 2006. From 2006 through 2011, emissions have fluctuated due to the economic recession and associated decrease in demand for construction materials. Overall, from 1990 to 2011, emissions from cement production decreased by 1.6 Tg CO_2e (4.9 percent).
- Net CO_2 uptake from LULUCF grew by 110.5 Tg CO_2e (13.9 percent) from 1990 through 2011. This increase was primarily due to a higher rate of net carbon accumulation in forest carbon stocks, particularly in above-ground and below-ground tree biomass, and harvested wood pools. Annual carbon accumulation in landfilled yard trimmings and food scraps slowed over this period, while the rate of carbon accumulation in urban trees accelerated.

Methane Emissions

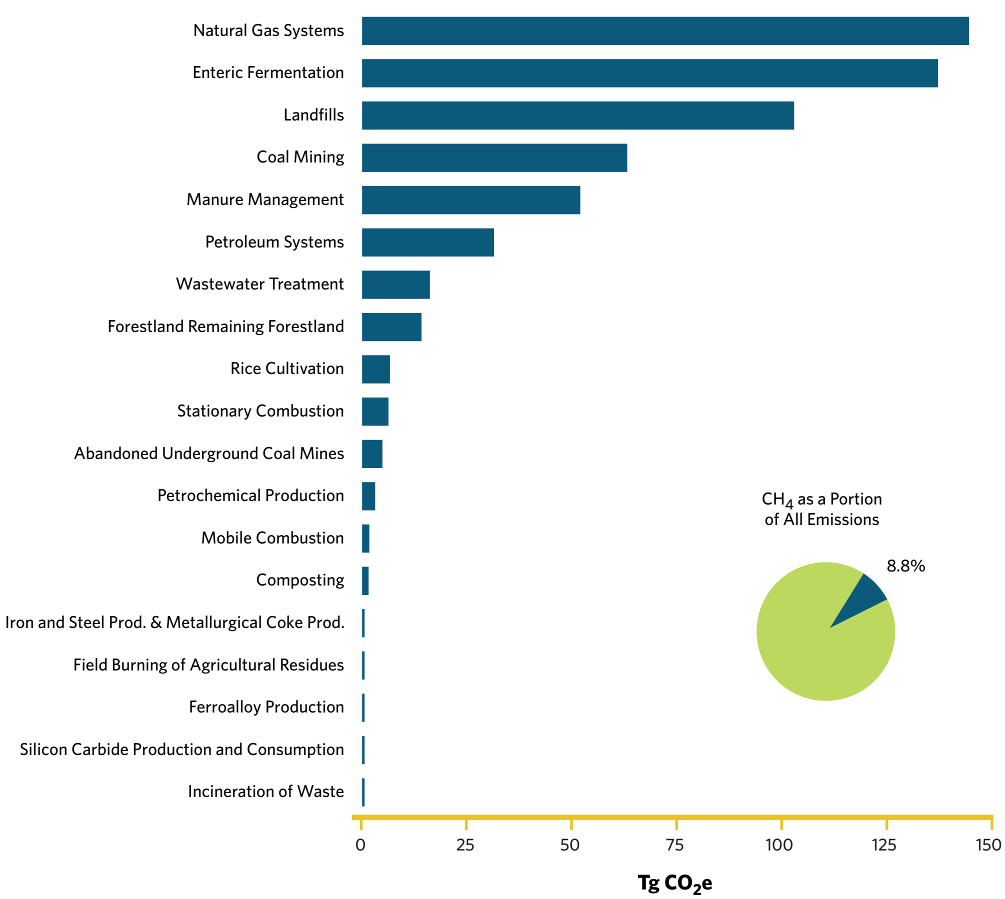
CH_4 is more than 20 times as effective as CO_2 at trapping heat in the atmosphere (IPCC 1996). Over the last 250 years, the concentration of CH_4 in the atmosphere increased by 158 percent (IPCC 2007). Anthropogenic sources of CH_4 include natural gas and petroleum systems, agricultural activities, landfills, coal mining, wastewater treatment, stationary and mobile combustion, and certain industrial processes (Figure 3-8).

Some significant trends in U.S. emissions of CH_4 include:

- Natural gas systems were the largest anthropogenic source category of CH_4 emissions in the United States in 2011, with 144.7 Tg CO_2e of CH_4 emitted into the atmosphere. This

Figure 3-8 **2011 U.S. Sources of Methane Emissions**

In 2011, CH_4 accounted for 8.8 percent of U.S. GHG emissions on a global warming potential-weighted basis. Natural gas systems comprised the largest source of CH_4, accounting for 144.7 Tg CO_2e, or 24.6 percent of total CH_4 emissions. Enteric fermentation followed close behind, contributing 137.4 Tg CO_2e, or 23.4 percent.



represented a 16.5 Tg CO_2e (10.2 percent) decrease since 1990, largely due to lower emissions from transmission and storage resulting from both increased voluntary reductions and decreased distribution emissions from cast iron and steel pipelines. Emissions from field production accounted for approximately 37 percent of CH_4 emissions from natural gas systems in 2011.

CH_4 emissions from field production decreased by 12 percent from 1990 through 2011. However, the trend was not stable over the time series. Emissions from field production rose by 43 percent from 1990 through 2006, and then declined by 38 percent from 2006 to 2011. The drivers of this trend include increased voluntary reductions and the effects of the recent global economic slowdown.

- Enteric fermentation is the second-largest anthropogenic source of CH_4 emissions in the United States. In 2011, CH_4 emissions from enteric fermentation were 137.4 Tg CO_2e (23.4 percent of total CH_4 emissions), an increase of 4.6 Tg CO_2e (3.5 percent) since 1990. This increase generally follows the trends in cattle populations. From 1990 through 1995, emissions from enteric fermentation rose, but then fell from 1996 through 2001, mainly due to fluctuations in beef cattle populations and improved digestibility of feed for feedlot cattle. Emissions generally increased from 2002 through 2007, though with a slight decrease in 2004, as both dairy and beef cattle populations grew and the literature for dairy cow diets indicated poorer feed digestibility for those years. Emissions decreased again from 2008 through 2011, as beef cattle populations again declined.
- Landfills are the third-largest anthropogenic source of CH_4 emissions in the United States, accounting for 17.5 percent of total CH_4 emissions (103.0 Tg CO_2e) in 2011. From 1990 through 2011, CH_4 emissions from landfills decreased by 44.7 Tg CO_2e (30.3 percent), with small increases occurring in some interim years, despite the higher volume of municipal solid waste (MSW) placed in landfills. This downward trend can be attributed to a 21 percent reduction in decomposable materials (i.e., paper and paperboard, food scraps, and yard trimmings) discarded in MSW landfills over the time series, and an increase in landfill gas collected and combusted.[9]
- In 2011, CH_4 emissions from coal mining were 63.2 Tg CO_2e—a 9.2 Tg CO_2e (12.6 percent) decrease from 2010 emission levels. The overall decline of 20.8 Tg CO_2e (24.8 percent) from 1990 resulted from the mining of less gassy coal from underground mines and the increased use of CH_4 collected from degasification systems.
- Methane emissions from manure management rose by 65.3 percent, from 31.5 Tg CO_2e in 1990 to 52.0 Tg CO_2e in 2011. The majority of this increase was from swine and dairy cow manure, reflecting the general trend in manure management toward greater use of liquid systems, which increases CH_4 emissions. This trend is the combined result of a shift to larger facilities, and to facilities in the West and Southwest, all of which tend to use liquid systems. Also, new regulations limiting the application of manure nutrients have shifted manure management practices at smaller dairies from daily spread to manure managed and stored on site.

Nitrous Oxide Emissions

N_2O is produced by biological processes that occur in soil and water and by a variety of anthropogenic activities in the agricultural, energy-related, industrial, and waste management fields. While total N_2O emissions are much lower than CO_2 emissions, N_2O is approximately 300 times more powerful than CO_2 at trapping heat in the atmosphere (IPCC 1996). Since 1750, the global atmospheric concentration of N_2O has risen by approximately 19 percent (IPCC 2007). The main U.S. anthropogenic activities producing N_2O are agricultural soil management, stationary fuel combustion, fuel combustion in motor vehicles, manure management, and nitric acid production (Figure 3-9).

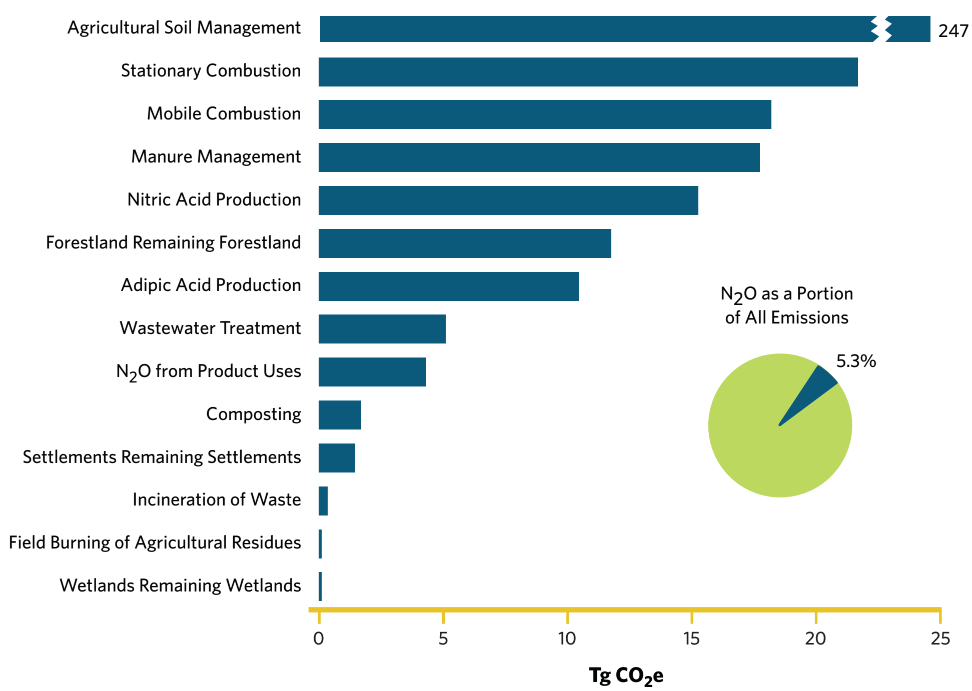
Some significant trends in U.S. emissions of N_2O include:

- Agricultural soils accounted for approximately 69.3 percent (247.2 Tg CO_2e) of N_2O emissions and 3.7 percent of total emissions in the United States in 2011. Annual N_2O emissions

[9] The CO_2 produced from combusted CH_4 at landfills is not counted in national inventories, as it is considered part of the natural carbon cycle of decomposition.

Figure 3-9 **2011 U.S. Sources of Nitrous Oxide Emissions**

In 2011, N_2O accounted for 5.3 percent of U.S. GHG emissions on a global warming potential-weighted basis. Agricultural soil management was the largest U.S. source of N_2O, producing 247.2 Tg CO_2e, or 69.3 percent of N_2O emissions.



from agricultural soils fluctuated between 1990 and 2011, although overall emissions were 8.5 percent higher in 2011 than in 1990. The annual fluctuation was largely a reflection of annual variation in weather patterns, synthetic fertilizer use, and crop production.

- N_2O emissions from stationary combustion increased by 9.7 Tg CO_2e (79.3 percent) from 1990 through 2011, primarily as a result of the growth of coal fluidized bed boilers in the electric power sector.
- In 2011, mobile combustion produced 18.5 Tg CO_2e (5.2 percent) of U.S. N_2O emissions. Although N_2O emissions from mobile combustion decreased by 58.0 percent from 1990 through 2011, they increased by 25.6 percent from 1990 through 1998, because of control technologies that reduced NO_x emissions but boosted N_2O emissions. Since 1998, newer control technologies have led to an overall decline of 36.8 Tg CO_2e (66.6 percent) in N_2O from this source.
- N_2O emissions from adipic acid production were 10.6 Tg CO_2e in 2011, and have decreased significantly in recent years due to the widespread installation of pollution control measures.

HFC, PFC, and SF_6 Emissions

HFCs are a family of synthetic chemicals that are used as alternatives to ozone-depleting substances (ODS), which are being phased out under the 1987 Montreal Protocol and 1990 Clean Air Act Amendments. Because HFCs and PFCs do not deplete the stratospheric ozone layer, they are acceptable alternatives under the Montreal Protocol.

PFCs are another family of synthetic chemicals that are emitted primarily from the production of semiconductors and as a by-product during the production of primary aluminum. A small amount of PFCs, which like HFCs do not deplete the ozone layer, are also used as alternatives to ODS.

However, these compounds, along with SF_6, are potent GHGs. Besides having high GWPs, SF_6 and PFCs have extremely long atmospheric lifetimes, resulting in their essentially irreversible accumulation in the atmosphere once emitted.

In addition to the use of HFCs and PFCs as alternatives to ODS, other sources of these gases include electrical transmission and distribution systems, HCFC-22 production, semiconductor manufacturing, aluminum production, and magnesium production and processing (Figure 3-10).

Some significant trends in U.S. HFC, PFC, and SF_6 emissions include:

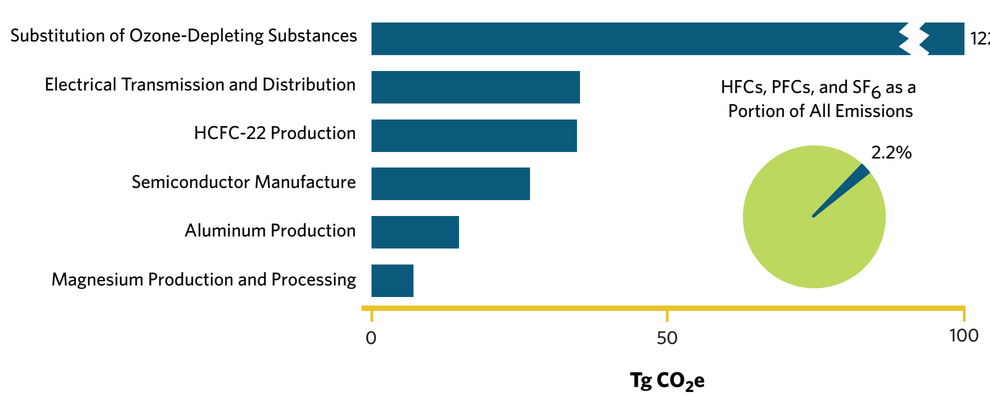
- Emissions resulting from the substitution of ODS (e.g., chlorofluorocarbons [CFCs]) have been consistently increasing, from 0.3 Tg CO_2e in 1990 to 121.7 Tg CO_2e in 2011. Emissions from ODS substitutes are both the largest and the fastest-growing source of HFC, PFC, and SF_6 emissions. These emissions have been increasing since the phase-out of ODS required under the Montreal Protocol came into effect, especially after 1994, when the first generation of new technologies featuring ODS substitutes fully penetrated the market (excluding most aerosols, from which CFCs were banned in 1978).
- HFC emissions from the production of HCFC-22 decreased by 29.5 Tg CO_2e (81.0 percent) from 1990 through 2011. This reduction was due to (1) a steady decline in the emission rate of HFC-23 (i.e., the amount of HFC-23 emitted/kg of HCFC-22 manufactured); (2) the use of thermal oxidation at some plants to reduce HFC-23 emissions; and (3) a decrease in the domestic production of HCFC-22 as Montreal Protocol and Clean Air Act restrictions took effect.
- SF_6 emissions from electric power transmission and distribution systems decreased by 19.6 Tg CO_2e (73.6 percent) from 1990 through 2011, primarily because of higher purchase prices for SF_6 and efforts by industry to reduce emissions.
- PFC emissions from aluminum production decreased by 15.5 Tg CO_2e (84.0 percent) from 1990 through 2011, due to both industry emission reduction efforts and declines in domestic aluminum production.

OVERVIEW OF SECTOR EMISSIONS AND TRENDS

In accordance with the *Revised 1996 IPCC Guidelines* (IPCC/UNEP/OECD/IEA 1997) and the 2003 *UNFCCC Guidelines on Reporting and Review* (UNFCCC 2003), Figure 3-11 and Table 3-4 aggregate emissions and sinks by sectors, as defined by the IPCC. Emissions of all gases can be summed from each source category from IPCC guidance. From 1990 through 2011, total emissions in the energy, industrial processes, and agriculture sectors grew by 478.4 Tg CO_2e (9.1 percent), 10.3 Tg CO_2e (3.3 percent), and 47.6 Tg CO_2e (11.5 percent), respectively.

Figure 3-10 **2011 U.S. Sources of Hydrofluorocarbons, Perfluorocarbons, and Sulfur Hexafluoride Emissions**

In 2011, HFCs, PFCs, and SF_6 accounted for 2.2 percent of U.S. GHG emissions on a global warming potential-weighted basis. Emissions from the substitution of ozone-depleting substances (e.g., chlorofluorocarbons) have been consistently increasing, from 0.3 Tg CO_2e in 1990 to 121.7 Tg CO_2e in 2011.



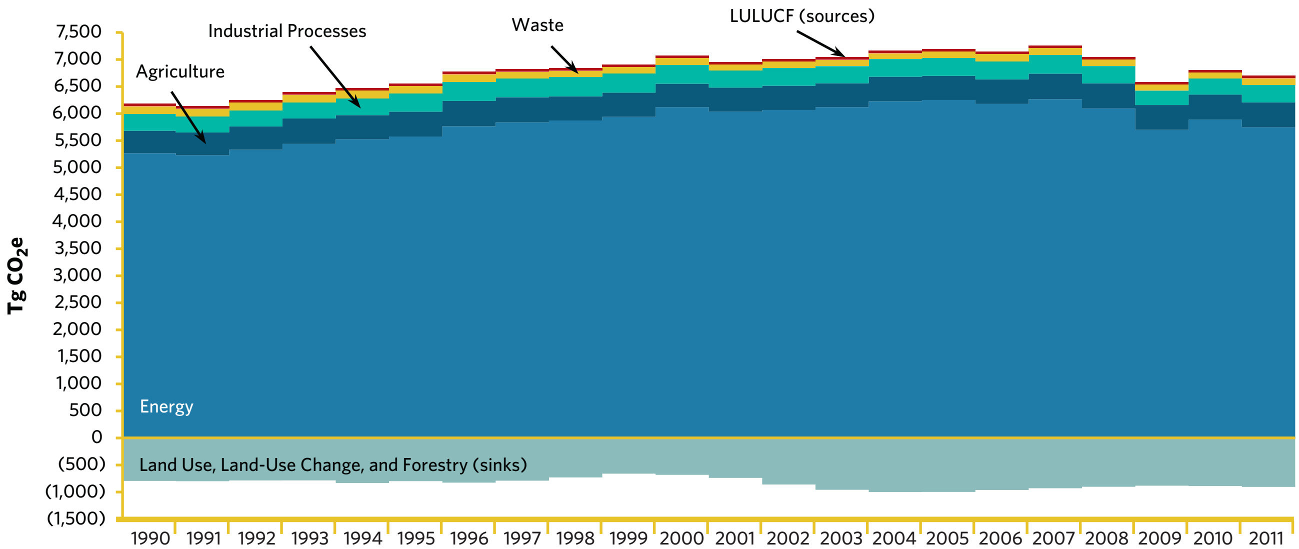
Emissions from the waste and solvent and other product use sectors decreased by 40.2 Tg CO_2e (23.9 percent) and by less than 0.1 Tg CO_2e (0.4 percent), respectively. Over the same period, estimates of net carbon sequestration in the LULUCF sector (magnitude of emissions plus CO_2 flux from all LULUCF source categories) increased by 87.6 Tg CO_2e (11.2 percent).

Energy

The energy sector produces emissions of all GHGs resulting from stationary and mobile energy activities, including fuel combustion and fugitive fuel emissions. Energy-related activities—primarily fossil fuel combustion—accounted for the vast majority of U.S. CO_2 emissions from 1990 through 2011. In 2011, approximately 87 percent of the energy consumed in the

Figure 3-11 **U.S. Greenhouse Gas Emissions and Sinks by IPCC Sector**

Along with Table 3-4, this figure aggregates emissions and sinks by sectors, as defined by the Intergovernmental Panel on Climate Change. Since 2007 (2010 CAR data), GHG emissions in all sectors have decreased, and net sequestration from land use, land-use change, and forestry (LULUCF) have remained relatively stable.



Source: U.S. EPA/OAP 2013.

Table 3-4 **Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by IPCC Sector** (Tg CO_2e)

From 1990 to 2011, total emissions in the energy, industrial processes, and agriculture sectors increased, emissions in the solvent and other product use sector remained unchanged, and emissions in the waste sector decreased. Net sequestration in the land-use change and forestry sector increased by 408.6 Tg CO_2e, or 13.9 percent.

IPCC Sector	1990	2005	2007	2008	2009	2010	2011
Energy	5,267.3	6,251.6	6,266.9	6,096.2	5,699.2	5,889.1	5,745.7
Industrial Processes	316.1	330.8	347.2	318.7	265.3	303.4	326.5
Solvent and Other Product Use	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Agriculture	413.9	446.2	470.9	463.6	459.2	462.3	461.5
Land-Use Change and Forestry	13.7	25.4	37.3	27.2	20.4	19.7	36.6
Waste	167.8	136.9	136.5	138.6	138.1	131.4	127.7
Total Emissions	**6,183.3**	**7,195.3**	**7,263.2**	**7,048.8**	**6,586.6**	**6,810.3**	**6,702.3**
Land-Use Change and Forestry (Sinks)	*(794.5)*	*(997.8)*	*(929.2)*	*(902.6)*	*(882.6)*	*(888.8)*	*(905.0)*
Net Emissions (Emissions and Sinks)	**5,388.7**	**6,197.4**	**6,334.0**	**6,146.2**	**5,704.0**	**5,921.5**	**5,797.3**

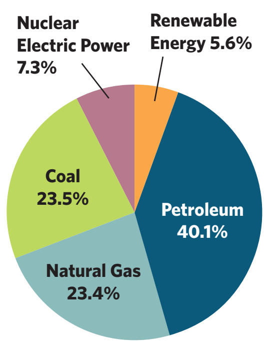
* The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in net emissions total.

Note: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration. IPCC = Intergovernmental Panel on Climate Change.

United States (on a British thermal unit basis) was produced by the combustion of fossil fuels; the remaining 13 percent was produced by other sources, such as hydroelectric, biomass, nuclear, wind, and solar energy (Figure 3-12). Energy-related activities are also responsible for CH_4 and N_2O emissions (43 percent and 11 percent of total U.S. emissions, respectively). Overall, emission sources in the energy sector accounted for a combined 85.7 percent of total U.S. GHG emissions in 2011.

Figure 3-12 **2011 U.S. Energy Consumption by Energy Source**

In 2011, approximately 87 percent of U.S. energy consumed was produced by the combustion of fossil fuels. The remaining 13 percent was produced by other sources, such as hydroelectric, biomass, nuclear, wind, and solar energy.



Industrial Processes

The industrial processes sector contains by-products or fugitive emissions of GHGs from industrial processes not directly related to energy activities, such as fossil fuel combustion. For example, industrial processes can chemically transform raw materials, which often release waste gases, such as CO_2, CH_4, and N_2O. These processes include iron and steel production and metallurgical coke production, cement production, ammonia production and urea consumption, lime production, other process uses of carbonates (e.g., flux stone, flue gas desulfurization, and glass manufacturing), soda ash production and consumption, titanium dioxide production, phosphoric acid production, ferroalloy production, glass production, CO_2 consumption, silicon carbide production and consumption, aluminum production, petrochemical production, nitric acid production, adipic acid production, lead production, and zinc production. Additionally, emissions from industrial processes release HFCs, PFCs, and SF_6. Overall, emission sources in the industrial process sector accounted for 4.9 percent of U.S. GHG emissions in 2011.

Solvent and Other Product Use

The solvent and other product use sector contains GHG emissions that are produced as a by-product of various solvent and other product uses. In the United States, emissions from N_2O from product uses, the only source of GHG emissions from this sector, accounted for about 0.1 percent of total U.S. anthropogenic GHG emissions on a carbon-equivalent basis in 2011.

Agriculture

The agricultural sector contains anthropogenic emissions from agricultural activities (except fuel combustion, which is addressed in the energy sector, and agricultural CO_2 fluxes, which are addressed in the LULUCF sector). Agricultural activities contribute directly to emissions of GHGs through a variety of processes, including the enteric fermentation in domestic livestock, livestock manure management, rice cultivation, agricultural soil management, and field burning of agricultural residues. CH_4 and N_2O were the primary GHGs emitted by agricultural activities. CH_4 emissions from enteric fermentation and manure management represented 23.4 percent and 8.9 percent of total, CH_4 emissions from anthropogenic activities in 2011, respectively. Agricultural soil management activities, such as fertilizer application and other cropping practices, were the largest source of U.S. N_2O emissions in 2011, accounting for 69.3 percent. In 2011, emission sources accounted for in the agricultural sector were responsible for 6.9 percent of total U.S. GHG emissions.

Land Use, Land-Use Change, and Forestry

The LULUCF sector contains emissions of CH_4 and N_2O, and emissions and removals of CO_2 from forest management, other land-use activities, and land-use change. Forest management practices, tree planting in urban areas, the management of agricultural soils, and the landfilling of yard trimmings and food scraps resulted in a net uptake (sequestration) of carbon in the United States. Forests (including vegetation, soils, and harvested wood) accounted for 92 percent of total 2011 net CO_2 flux, urban trees accounted for 8 percent, mineral and organic soil carbon stock changes accounted for 1 percent, and landfilled yard trimmings and food scraps accounted for 1 percent of the total net flux in 2011.

The net forest sequestration is a result of net forest growth and increasing forest area, as well as a net accumulation of carbon stocks in harvested wood pools. The net sequestration in urban forests is a result of net tree growth in these areas. In agricultural soils, mineral and organic soils sequester approximately five times as much carbon as is emitted from these soils through liming and urea fertilization. The mineral soil carbon sequestration is largely due to the conversion of cropland to permanent pastures, grasslands, and hay production, a reduction in summer fallow areas in semi-arid areas, an increase in the adoption of conservation tillage practices, and an increase in the amounts of organic fertilizers (i.e., manure and sewage sludge) applied to agricultural lands. The net sequestration from yard trimmings and food scraps is due to the long-term accumulation of carbon from yard trimmings and food scraps in landfills.

LULUCF activities in 2011 resulted in a net carbon sequestration of 905.0 Tg CO_2e (Table 3-5). This represents an offset of 16.1 percent of total U.S. CO_2 emissions, or 13.5 percent of total GHG emissions in 2011. Between 1990 and 2011, total LULUCF net carbon flux resulted in a 13.9 percent increase in CO_2 sequestration, primarily due to an increase in the rate of net carbon accumulation in forest carbon stocks, particularly in above-ground and below-ground tree biomass, and harvested wood pools. Annual carbon accumulation in landfilled yard trimmings and food scraps slowed over this period, while the rate of annual carbon accumulation increased in urban trees.

Emissions from LULUCF are shown in Table 3-6. Liming of agricultural soils and urea fertilization in 2011 resulted in CO_2 emissions of 8.1 Tg CO_2e (8,117 gigagrams [Gg]). Lands undergoing peat extraction (i.e., peatlands remaining peatlands) resulted in CO_2 emissions of 0.9 Tg CO_2e (918 Gg), and N_2O emissions of less than 0.05 Tg CO_2e. The application of synthetic fertilizers to forest soils in 2011 resulted in direct N_2O emissions of 0.4 Tg CO_2e (1 Gg). Direct N_2O emissions from fertilizer application to forest soils have increased by 455 percent since 1990, but still account for a relatively small portion of overall emissions. Additionally, direct N_2O emissions from fertilizer application to settlement soils in 2011 accounted for 1.5 Tg CO_2e (5 Gg), representing an increase of 51 percent since 1990. Forest fires in 2011 resulted in CH_4 emissions of 14.2 Tg CO_2e (675 Gg), and in N_2O emissions of 11.6 Tg CO_2e (37 Gg).

Waste

The waste sector contains emissions from waste management activities (except incineration of waste, which is addressed in the energy sector). Landfills were the largest source of anthropogenic GHG emissions in the waste sector, accounting for 80.7 percent of this sector's emissions, and 17.5 percent of total U.S. CH_4 emissions.[10] Additionally, wastewater treatment accounts for 16.7 percent of waste emissions, 2.8 percent of U.S. CH_4 emissions, and 1.5 percent of U.S. N_2O emissions. Emissions of CH_4 and N_2O from composting are also accounted for in this sector, generating emissions of 1.5 Tg CO_2e and 1.7 Tg CO_2e, respectively. Overall, emission sources accounted for in the waste sector generated 1.9 percent of total U.S. GHG emissions in 2011.

[10] Landfills also store carbon, due to incomplete degradation of organic materials, such as wood products and yard trimmings, as described in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011* (U.S. EPA/OAP 2013).

Table 3-5 **Net CO_2 Flux from Land Use, Land-Use Change, and Forestry** (Tg CO_2e)

Between 1990 and 2011, total LULUCF net carbon flux resulted in a 13.9 percent increase in CO_2 sequestration, primarily due to an increase in the rate of net carbon accumulation in forest carbon stocks, particularly in above-ground and below-ground tree biomass, and harvested wood pools.

Sink Category	1990	2005	2007	2008	2009	2010	2011
Forestland Remaining Forestland	(696.8)	(905.0)	(859.3)	(833.3)	(811.3)	(817.6)	(833.5)
Cropland Remaining Cropland	(34.1)	(20.3)	(6.6)	(5.2)	(4.6)	(3.0)	(2.9)
Land Converted to Cropland	21.0	13.5	14.5	14.5	14.5	14.5	14.5
Grassland Remaining Grassland	(5.3)	(1.0)	7.1	7.2	7.3	7.3	7.4
Land Converted to Grassland	(7.7)	(10.2)	(9.0)	(9.0)	(8.9)	(8.8)	(8.8)
Settlements Remaining Settlements	(47.5)	(63.2)	(65.0)	(66.0)	(66.9)	(67.9)	(68.8)
Other (Landfilled Yard Trimmings and Food Scraps)	(24.2)	(11.6)	(10.9)	(10.9)	(12.7)	(13.3)	(13.0)
Total	**(794.5)**	**(997.8)**	**(929.2)**	**(902.6)**	**(882.6)**	**(888.8)**	**(905.0)**

Note: Totals may not sum due to independent rounding. Parentheses indicate net sequestration.

Table 3-6 **Emissions from Land Use, Land-Use Change, and Forestry** (Tg CO_2e)

Between 1990 and 2011, CH_4 emissions from forest fires rose by 407.1 percent, and direct N_2O emissions from fertilizer application to forest soils rose by 455 percent. While these increases are significant, these sources account for a relatively small portion of overall GHG emissions.

Source Category	1990	2005	2007	2008	2009	2010	2011
Carbon Dioxide (CO_2)	**8.1**	**8.9**	**9.2**	**9.6**	**8.3**	**9.4**	**9.0**
Cropland Remaining Cropland: Liming of Agricultural Soils	4.7	4.3	4.5	5.0	3.7	4.7	4.5
Cropland Remaining Cropland: Urea Fertilization	2.4	3.5	3.8	3.6	3.6	3.7	5.3
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	1.0	1.1	1.0	1.0	1.1	1.0	0.9
Methane (CH_4)	**2.5**	**8.0**	**14.4**	**8.7**	**5.7**	**4.7**	**14.2**
Forestland Remaining Forestland: Forest Fires	2.5	8.0	14.4	8.7	5.7	4.7	14.2
Nitrous Oxide (N_2O)	**3.1**	**8.4**	**13.7**	**8.9**	**6.4**	**5.6**	**13.4**
Forestland Remaining Forestland: Forest Fires	2.0	6.6	11.7	7.1	4.7	3.8	11.6
Forestland Remaining Forestland: Forest Soils	0.1	0.4	0.4	0.4	0.4	0.4	0.4
Settlements Remaining Settlements: Settlement Soils	1.0	1.5	1.6	1.5	1.4	1.5	1.5
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	+	+	+	+	+	+	+
Total	**13.7**	**25.4**	**37.3**	**27.2**	**20.4**	**19.7**	**36.6**

+ Less than 0.05 Tg CO_2e.

Note: Totals may not sum due to independent rounding.

EMISSIONS BY ECONOMIC SECTOR

Throughout the 1990–2011 Inventory, emission estimates are grouped into six sectors defined by the IPCC: energy, industrial processes, solvent use, agriculture, LULUCF, and waste (U.S. EPA/OAP 2013). While it is important to use this characterization for consistency with UNFCCC reporting guidelines, it is also useful to allocate emissions into more commonly used domestic sectoral categories. This section reports emissions by the following economic sectors: residential, commercial, industry, transportation, electricity generation, agriculture, and U.S. territories. Table 3-7 summarizes emissions from each of these sectors, and Figure 3-13 shows the trend in emissions by sector from 1990 to 2011.

Using this categorization, emissions from electricity generation accounted for the largest portion (33 percent) of U.S. GHG emissions in 2011. Transportation activities, in aggregate, accounted for the second-largest portion (27 percent), while emissions from industry accounted for the third-largest portion (20 percent) of U.S. GHG emissions in 2011. In contrast to electricity generation and transportation, emissions from industry have in general declined over the past decade. The long-term decline in these emissions has been due to structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and energy efficiency improvements.

The remaining 20 percent of U.S. GHG emissions were contributed by, in order of importance, the agriculture, commercial, and residential sectors, plus emissions from U.S. territories. Activities related to agriculture accounted for 8 percent of U.S. emissions. Unlike other economic sectors, agricultural sector emissions were dominated by N_2O emissions from agricultural soil management and CH_4 emissions from enteric fermentation. The commercial and residential sectors accounted for 6 percent and 5 percent, respectively, of emissions, and U.S. territories accounted for 1 percent. Emissions from these three sectors primarily consisted of CO_2 emissions from fossil fuel combustion. CO_2 was also emitted and sequestered by a

Table 3-7 **U.S. Greenhouse Gas Emissions Allocated to Economic Sectors** (Tg CO_2e)

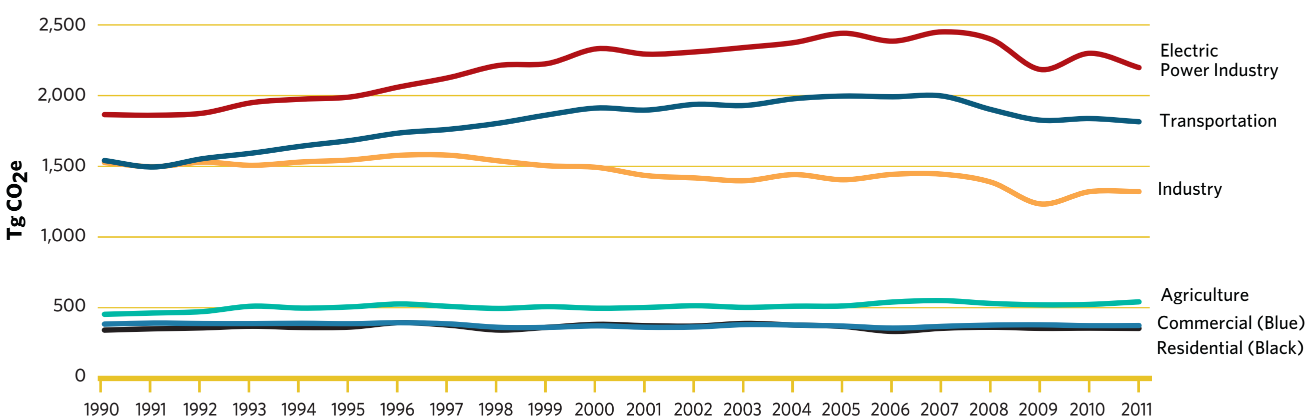
Between 2007 (2010 CAR data) and 2011, U.S. GHG emissions from major economic sectors decreased by 560.9 Tg CO_2e, or 7.7 percent. The long-term decline in these emissions has been due to structural changes in the U.S. economy, fuel switching, and energy efficiency improvements.

Implied Sectors	1990	2005	2007	2008	2009	2010	2011
Electric Power Industry	1,866.1	2,445.7	2,455.6	2,402.0	2,187.6	2,303.0	2,200.9
Transportation	1,553.2	2,012.3	2,013.1	1,916.0	1,840.6	1,852.2	1,829.4
Industry	1,538.8	1,416.2	1,456.1	1,398.8	1,244.2	1,331.8	1,332.0
Agriculture	458.0	517.4	555.6	535.3	525.4	528.7	546.6
Commercial	388.1	374.1	372.0	380.9	382.9	376.9	378.0
Residential	345.4	371.3	358.2	366.0	358.1	359.6	357.3
U.S. Territories	33.7	58.2	52.6	49.8	47.9	58.0	58.0
Total Emissions	**6,183.3**	**7,195.3**	**7,263.2**	**7,048.8**	**6,586.6**	**6,810.3**	**6,702.3**
Land Use, Land-Use Change, and Forestry (Sinks)	*(794.5)*	*(997.8)*	*(929.2)*	*(902.6)*	*(882.6)*	*(888.8)*	*(905.0)*
Net Emissions (Sources and Sinks)	**5,388.7**	**6,197.4**	**6,334.0**	**6,146.2**	**5,704.0**	**5,921.5**	**5,797.3**

Note: Totals may not sum due to independent rounding. Emissions include CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6. Parentheses indicate negative values or sequestration.

Figure 3-13 **U.S. Greenhouse Gas Emissions Allocated to Economic Sectors**

In 2011, electricity generation accounted for the largest portion (33 percent) of U.S. GHG emissions, transportation activities accounted for 27 percent, and industry accounted for 20 percent. In contrast to electricity generation and transportation, emissions from industry have generally declined over the past decade.



variety of activities related to forest management practices, tree planting in urban areas, the management of agricultural soils, and landfilling of yard trimmings.

Electricity is ultimately consumed in the economic sectors described above. Table 3-8 presents GHG emissions from economic sectors with emissions related to electricity generation distributed into end-use categories (i.e., emissions from electricity generation are allocated to the economic sectors in which the electricity is consumed). To distribute electricity emissions among end-use sectors, emissions from the source categories assigned to electricity generation were allocated to the residential, commercial, industry, transportation, and agriculture economic sectors according to retail sales of electricity.[11] These source categories include

[11] Emissions were not distributed to U.S. territories, since the electricity generation sector only includes emissions related to the generation of electricity in the 50 U.S. states and the District of Columbia.

CO_2 from fossil fuel combustion and the use of limestone and dolomite for flue gas desulfurization, CO_2 and N_2O from incineration of waste, CH_4 and N_2O from stationary sources, and SF_6 from electrical transmission and distribution systems.

When emissions from electricity are distributed among these sectors, industrial activities accounted for the largest share of U.S. GHG emissions (28 percent) in 2011. Transportation is the second-largest contributor to total U.S. GHG emissions (27 percent), and the residential and commercial sectors contributed the next-largest shares in 2011. Emissions from these sectors increase substantially when emissions from electricity are included, due to their relatively large share of electricity consumption (e.g., lighting, appliances). In all sectors except agriculture, CO_2 accounts for more than 80 percent of GHG emissions, primarily from the combustion of fossil fuels. Figure 3-14 and Box 3-3 show the trend in these emissions by sector from 1990 to 2011.

Table 3-8 **U.S Greenhouse Gas Emissions by Economic Sector with Electricity-Related Emissions Distributed** (Tg CO_2e)

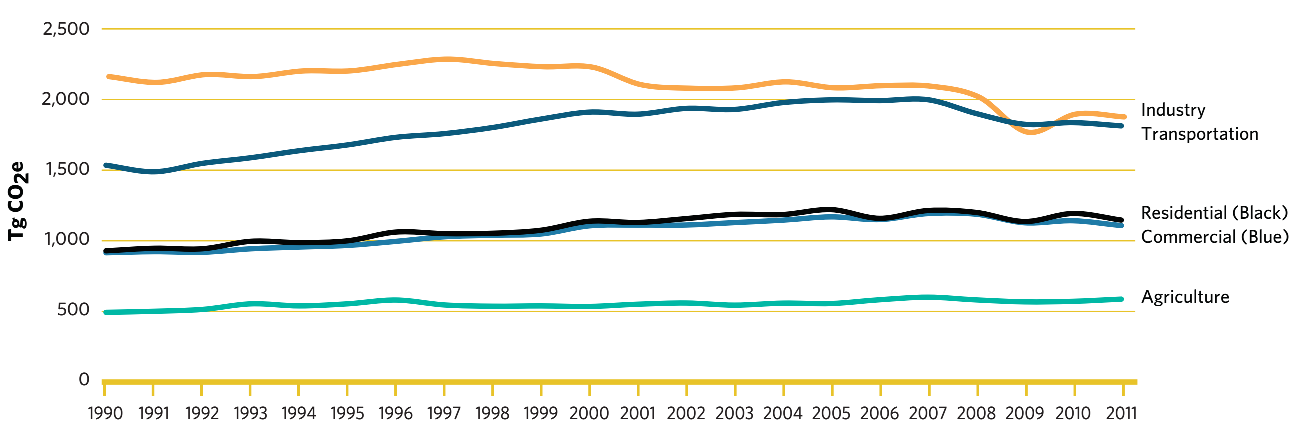
In 2011, after distributing emissions from electricity generation to end-use sectors, industry accounted for 28.3 percent of total U.S. GHG emissions, and the transportation sector accounted for 27.4 percent.

Implied Sectors	**1990**	**2005**	**2007**	**2008**	**2009**	**2010**	**2011**
Industry	2,181.3	2,102.4	2,113.6	2,036.3	1,789.8	1,916.9	1,897.2
Transportation	1,556.3	2,017.2	2,018.2	1,920.8	1,845.2	1,856.9	1,833.7
Residential	939.5	1,192.4	1,215.6	1,211.1	1,150.8	1,165.2	1,131.0
Commercial	953.1	1,243.6	1,237.1	1,223.6	1,159.6	1,216.3	1,169.8
Agriculture	519.3	581.5	626.2	607.1	593.3	597.1	612.6
U.S. Territories	33.7	58.2	52.6	49.8	47.9	58.0	58.0
Total Emissions	**6,183.3**	**7,195.3**	**7,263.2**	**7,048.8**	**6,586.6**	**6,810.3**	**6,702.3**
Land Use, Land-Use Change, and Forestry (Sinks)	*(794.5)*	*(997.8)*	*(929.2)*	*(902.6)*	*(882.6)*	*(888.8)*	*(905.0)*
Net Emissions (Sources and Sinks)	**5,388.7**	**6,197.4**	**6,334.0**	**6,146.2**	**5,704.0**	**5,921.5**	**5,797.3**

Note: Parentheses indicate negative values or sequestration.

Figure 3-14 **U.S. Greenhouse Gas Emissions with Electricity Distributed to Economic Sectors**

In 2011, after distributing emissions from electricity the major economic sectors, industrial activities accounted for 28 percent, and transportation accounted for 27 percent. In all sectors, GHG emissions declined from 2007 (2010 CAR data) to 2011.



Box 3-3 **Recent Trends in Various U.S. Greenhouse Gas Emissions-Related Data**

Total emissions can be compared with other economic and social indices to highlight changes over time. These comparisons include (1) emissions per unit of aggregate energy consumption, because energy-related activities are the largest sources of emissions; (2) emissions per unit of fossil fuel consumption, because almost all energy-related emissions involve the combustion of fossil fuels; (3) emissions per unit of electricity consumption, because the electric power industry—utilities and nonutilities combined—was the largest source of U.S. GHG emissions in 2011; (4) emissions per unit of total gross domestic product (GDP) as a measure of national economic activity; and (5) emissions per capita.

Table 3-9 provides data on various statistics related to U.S. GHG emissions normalized to 1990 as a baseline year. U.S. GHG emissions have grown at an average annual rate of 0.4 percent since 1990. This rate is slightly faster than that for total energy and fossil fuel consumption, and much slower than that for electricity consumption, overall GDP, and national population (Figure 3-15).

Table 3-9 **Recent Trends in Various U.S. Data** (Index 1990 = 100)

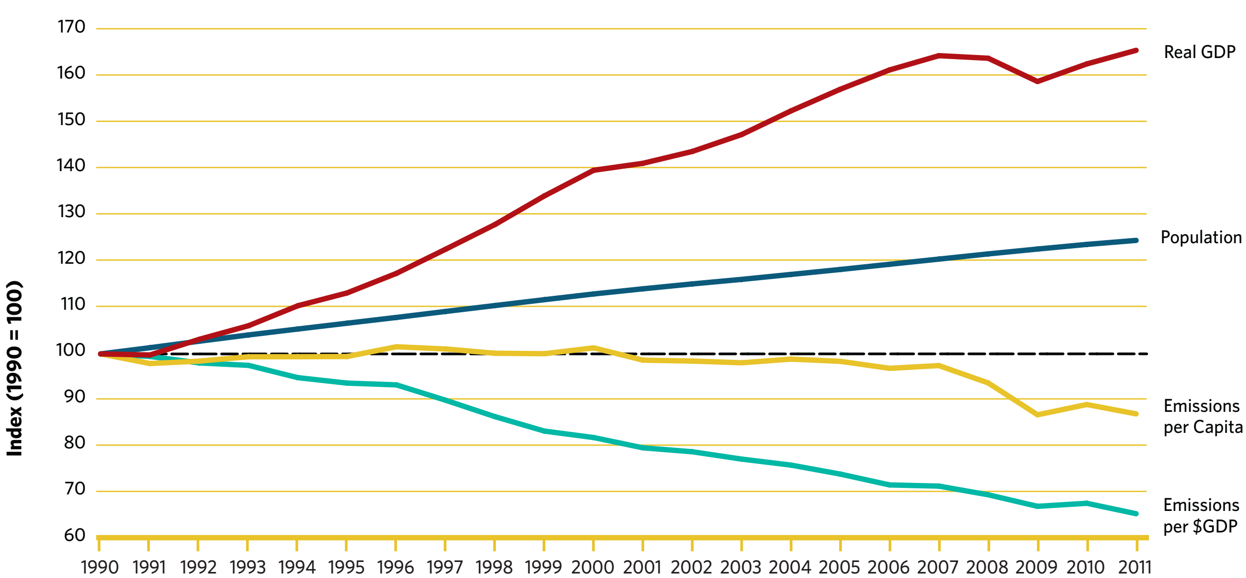
Since 1990, U.S. GHG emissions have grown at an average annual rate of 0.4 percent—slightly faster than the rate for total energy and fossil fuel consumption, and much slower than that for electricity consumption, overall GDP, and national population.

Variable	1990	2005	2007	2008	2009	2010	2011	Growth Rate[a]
Gross Domestic Product[b]	100	157	165	164	159	163	166	2.5%
Electricity Consumption[c]	100	134	137	136	131	137	136	1.5%
Fossil Fuel Consumption[c]	100	119	119	116	109	112	101	0.1%
Energy Consumption[c]	100	119	120	117	111	115	102	0.1%
Population[d]	100	118	121	122	123	124	125	1.1%
Greenhouse Gas Emissions[e]	100	116	117	114	107	110	108	0.4%

[a] Average annual growth rate.
[b] GDP in chained 2005 dollars (BEA 2012).
[c] Energy content-weighted values (EIA 2013).
[d] U.S. Census Bureau (2012).
[e] Global warming potential-weighted values.

Figure 3-15 **U.S. Greenhouse Gas Emissions per Capita and per Dollar of Gross Domestic Product**

Between 1990 and 2011, U.S. GHG emissions per capita and per dollar of GDP declined, despite increases in real GDP and population.



Sources: BEA 2012, U.S. Census Bureau 2012, and emission estimates in U.S. EPA/OAP 2013.

INDIRECT GREENHOUSE GAS EMISSIONS

The reporting requirements of the UNFCCC request that information be provided on indirect GHGs, which include CO, NO_x, NMVOCs, and SO_2 (UNFCCC 2006). These gases do not have a direct global warming effect, but indirectly affect terrestrial radiation absorption by influencing the formation and destruction of tropospheric and stratospheric ozone, or, in the case of SO_2, by affecting the absorptive characteristics of the atmosphere. Additionally, some of these gases may react with other chemical compounds in the atmosphere to form compounds that are GHGs.

CO is produced when carbon-containing fuels are combusted incompletely. NO_x (i.e., NO and NO_2) is created by lightning, fires, fossil fuel combustion, and in the stratosphere from N_2O. NMVOCs—which include hundreds of organic compounds that participate in atmospheric chemical reactions (e.g., propane, butane, xylene, toluene, ethane)—are emitted primarily from transportation, industrial processes, and nonindustrial consumption of organic solvents. In the United States, SO_2 is primarily emitted from coal combustion for electric power generation and the metals industry. Sulfur-containing compounds emitted into the atmosphere tend to exert a negative radiative forcing (i.e., cooling); therefore, they are discussed separately.

One important indirect climate change effect of NMVOCs and NO_x is their role as precursors for tropospheric ozone formation. They can also alter the atmospheric lifetimes of other GHGs. Another example of indirect GHG formation into direct GHGs is CO's interaction with the hydroxyl radical—the major atmospheric sink for CH_4 emissions—to form CO_2. Therefore, increased atmospheric concentrations of CO limit the number of hydroxyl molecules (OH) available to destroy CH_4.

Since 1970, the United States has published estimates of emissions of CO, NO_x, NMVOCs, and SO_2 (U.S. EPA/OAQPS 2009, 2010),[12] which are regulated under the Clean Air Act.[13] Table 3-10 shows that fuel combustion accounts for the majority of emissions of these indirect GHGs. Industrial processes—such as the manufacture of chemical and allied products, metals processing, and industrial uses of solvents—are also significant sources of CO, NO_x, and NMVOCs.

[12] NO_x and CO emission estimates from field burning of agricultural residues were estimated separately. Therefore, they were not taken from U.S. EPA/OAQPS 2009 or U.S. EPA/OAQPS 2010.

[13] Due to redevelopment of the information technology systems for the National Emission Inventory (NEI), publication of the most recent emissions for these pollutants was not available for the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2011* (U.S. EPA/OAP 2013). For an overview of the activities and the schedule for developing the 2011 NEI, with the goal of producing Version 1 in the summer of 2013, *see* EPA's NEI Plan of Activities at http://www.epa.gov/ttn/chief/eis/2011nei/2011plan.pdf.

Table 3-10 **Emissions of NO_x, CO, NMVOCs, and SO_2** (Tg)

Fuel combustion accounts for the majority of emissions of indirect GHGs. Industrial processes and industrial uses of solvents are also significant sources of CO, NO_x, and NMVOCs.

Gas/Activity	1990	2005	2007	2008	2009	2010	2011
Nitrogen Oxides (NO_x)	**21.7**	**15.9**	**14.4**	**13.5**	**11.5**	**11.5**	**11.5**
Mobile Fossil Fuel Combustion	10.9	9.0	8.0	7.4	6.2	6.2	6.2
Stationary Fossil Fuel Combustion	10.0	5.9	5.4	5.1	4.2	4.2	4.2
Industrial Processes	0.6	0.6	0.5	0.5	0.6	0.6	0.6
Oil and Gas Activities	0.1	+	+	+	+	+	+
Waste Combustion	0.1	+	+	+	+	+	+
Agricultural Burning	+	+	+	+	+	+	+
Solvent Use	+	+	+	+	+	+	+
Waste	+	+	+	+	+	+	+
Carbon Monoxide (CO)	**130.0**	**70.8**	**63.6**	**60.0**	**51.4**	**51.4**	**51.4**
Mobile Fossil Fuel Combustion	119.4	62.7	55.3	51.5	43.4	43.4	43.4
Stationary Fossil Fuel Combustion	5.0	4.6	4.7	4.8	4.5	4.5	4.5
Industrial Processes	4.1	1.6	1.6	1.7	1.5	1.5	1.5
Waste Combustion	1.0	1.4	1.4	1.4	1.4	1.4	1.4
Oil and Gas Activities	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Agricultural Burning	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Waste	+	+	+	+	+	+	+
Solvent Use	+	+	+	+	+	+	+
Non-Methane Volatile Organic Compounds (NMVOCs)	**20.9**	**13.8**	**13.4**	**13.3**	**9.3**	**9.3**	**9.3**
Mobile Fossil Fuel Combustion	10.9	6.3	5.7	5.4	4.2	4.2	4.2
Solvent Use	5.2	3.9	3.8	3.8	2.6	2.6	2.6
Industrial Processes	2.4	2.0	1.9	1.8	1.3	1.3	1.3
Oil and Gas Activities	0.6	0.5	0.5	0.5	0.6	0.6	0.6
Stationary Fossil Fuel Combustion	0.9	0.7	1.1	1.3	0.4	0.4	0.4
Waste Combustion	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Waste	0.7	0.1	0.1	0.1	+	+	+
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA
Sulfur Dioxide (SO_2)	**20.9**	**13.5**	**11.8**	**10.4**	**8.6**	**8.6**	**8.6**
Stationary Fossil Fuel Combustion	18.4	11.5	10.2	8.9	7.2	7.2	7.2
Industrial Processes	1.3	0.8	0.8	0.8	0.8	0.8	0.8
Mobile Fossil Fuel Combustion	0.8	0.9	0.6	0.5	0.5	0.5	0.5
Oil and Gas Activities	0.4	0.2	0.2	0.2	0.2	0.2	0.2
Waste Combustion	+	+	+	+	+	+	+
Waste	+	+	+	+	+	+	+
Solvent Use	+	+	+	+	+	+	+
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA

Sources: U.S. EPA 2009 and 2010, except for estimates from field burning of agricultural residues.
+ Does not exceed 0.5 Tg.
Notes: Totals may not sum due to independent rounding. NA = Not Available.